

PCT

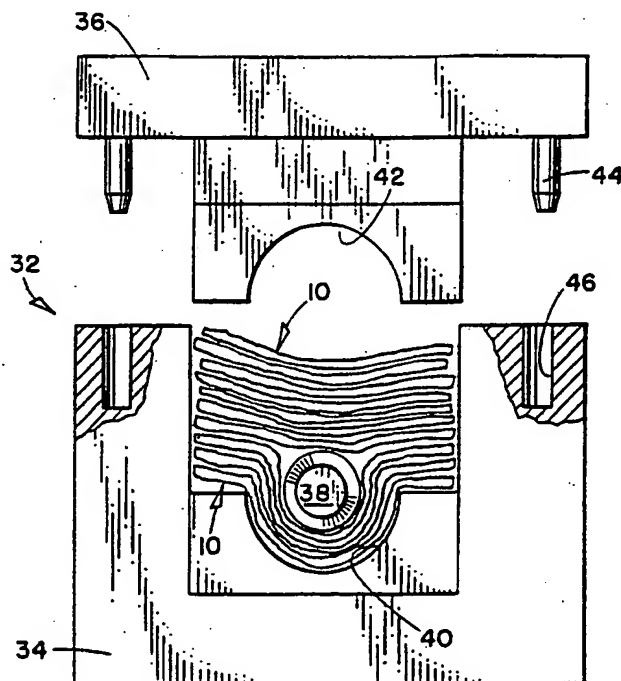
WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁵ : E21B 33/12, B29C 67/14</p>	<p>A1</p>	<p>(11) International Publication Number: WO 92/20899 (43) International Publication Date: 26 November 1992 (26.11.92)</p>
<p>(21) International Application Number: PCT/US92/04365 (22) International Filing Date: 21 May 1992 (21.05.92) (30) Priority data: 705,280 24 May 1991 (24.05.91) US (71) Applicant: THE GATES RUBBER COMPANY [US/US]; 990 South Broadway, Denver, CO 80209 (US). (72) Inventor: ELLIS, Paul, R. ; 6900 W. Yale Avenue, Denver, CO 80227 (US). (74) Agents: ISAAC, John, L. et al.; The Gates Rubber Com- pany, Patent/Legal Dept., 900 S. Broadway, Denver, CO 80209 (US).</p>		<p>(81) Designated States: AT (European patent), AU, BE (Euro- pean patent), BR, CA, CH (European patent), DE (Euro- pean patent), DK, DK (European patent), ES (Euro- pean patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, KR, LU (European patent), MC (European patent), NL (European patent), NO, RU, SE (European patent). Published With international search report.</p>

(54) Title: EXPENDABLE COMPOSITE FIBER DEVICE



(57) Abstract

An expendable, molded device is disclosed. The device is a composite of resin and fiber molded into a preselected shape. The composite includes an effective amount of fiber having an aspect ratio sufficient to produce a device with high compressive and tensile strength but having limited abrasion resistance. Use: Tools for earth drilling.

BEST AVAILABLE COPY

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	MI	Mali
AU	Australia	FR	France	MN	Mongolia
BB	Barbados	GA	Gabon	MR	Mauritania
BE	Belgium	GB	United Kingdom	MW	Malawi
BF	Burkina Faso	GN	Guinea	NL	Netherlands
BG	Bulgaria	GR	Greece	NO	Norway
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IE	Ireland	RO	Romania
CA	Canada	IT	Italy	RU	Russian Federation
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland	KR	Republic of Korea	SN	Senegal
CI	Côte d'Ivoire	LJ	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

EXPENDABLE COMPOSITE FIBER DEVICE

Background of the InventionField of the Invention

The present invention relates to metal replacement components or parts and, more particularly, to composite structures for metal replacement. Specifically, the present invention relates to devices having high tensile and compressive strengths yet are readily expendable by abrasive destruction.

Description of the Prior Art

Many components and tools in a wide variety of industries and product applications are made from steel, iron, aluminum and other metals because of their useful physical properties. A few of the major physical properties of such metal components and tools are their hardness, their high tensile strength as well as their high compressive strength. There is currently a desire in a variety of industries, as well as in a variety of product applications, to replace at least some of these metal components or tools with components or tools made from a nonmetallic material. A major concern for such alternative materials has generally been weight, although the material selected must perform all the functions of the original metal components or tools. One such industry is the aircraft industry wherein metal parts, including wing skin, have been replaced with composite material in lieu of metals. Likewise, the automobile industry has replaced numerous trim parts and body parts with composite materials in lieu of the original metal materials, again reducing weight while maintaining strength and environmental resistance.

One industry of particular concern is the well drilling industry wherein many parts and tools are metal and used for their physical property of high tensile and compressive

1 strength. In this particular industry, many of these parts
and tools need to be placed in a well, used, and then
"drilled through" or abraded away at a later time rather
than being physically removed from the well in tact.
5 Typically, drill bits designed specifically to drill through
rock are not of an optimum or especially desirable design
for drilling through and destroying such metal components or
tools. This situation necessitates either accepting a much
10 slower rate of travel of the rock drill bit while it is in
fact drilling through the metal component and abrading it,
or pulling what is possibly an extremely long string of pipe
from the well bore in order to attach a different style of
drill bit onto the end of the string and then sending it
back down into the well to drill through the metal part.
15 The selected method employed is generally determined by the
then current depth of the well as opposed to the rate at
which the then current "rock bit" is able to drill through
the metal parts. In either event, each of these two methods
of drilling through and expending the metal part or tool
20 substantially decreases the average drilling rate of travel,
which is a highly undesirable situation in the drilling
industry.

In the above instance, it is a desire in the drilling
industry to replace at least some of these metal tools or
25 components with tools or components made from a nonmetal
material that can be more easily and more quickly drilled
through with standard rock drilling bits, while at the same
time performing all the other functions of the original
metal downhole parts or tools. Examples of such tools
30 include mandrels and plugs, while inflatable packer elements
may also be included in this grouping.

A wide variety of different materials have been
investigated for the purpose of replacing metal parts or
tools. Such materials have included a wide variety of
35 plastics as well as a range of phenolic resins, either
unreinforced, filled with powers, or filled with short
fibers (i.e. 1/4 inch or less) of cotton or glass. While
these phenolic resin materials have been satisfactory for
fabricating some specific parts which perform certain

1 functions, many metal replacement opportunities are not open
to such materials because the tensile strengths, sheer
strengths, stiffness and other important properties are not
anywhere near those of the metal materials which are to be
5 replaced. This is particularly true in the well drilling
industry, wherein metal replacement parts and tools have
been manufactured from phenolic resins reinforced with short
fibers of glass. Thus, there remains a distinct need in
many industries and product applications for metal
10 replacement parts, components and tools capable of meeting
all of the desirable and needed physical properties
equivalent to those of the original metal components or
tools.

15 Summary of the Invention

Accordingly, it is one object of the present invention
to provide metal replacement components and tools having the
same or better physical properties as those of the original
20 metal components and tools which are being replaced.

It is another object of the present invention to
provide a composite material capable of being molded to
various shapes and forms to provide nonmetallic parts and
tools.

25 It is yet another object of the present invention to
provide nonmetallic substitute parts and tools which are
expendable and readily abraded.

A further object of the present invention is to provide
a composite material molded into a preselected shape to form
30 components and tools for the well drilling industry which
are readily drilled through.

To achieve the foregoing and other objects and in
accordance with a purpose of the present invention, as
embodied and broadly described herein, an expendable, molded
35 device is disclosed. The device is preferably a composite
of resin and fiber molded into a preselected shape. The
composite includes an effective amount of fiber having an
aspect ratio sufficient to produce a device with high
compressive and tensile strength but having limited abrasion

1 resistance. In one particularly preferred embodiment of the
invention, the device is in the form of a downhole tool for
use in a well bore, wherein the composite fiber aspect ratio
provides a sufficiently low abrasion resistance to permit
5 the tool to be destroyed by drilling using a rock drill bit.

Brief Description of the Drawings

The accompanying drawings, which are incorporated in
10 and form a part of the specification, illustrate preferred
embodiments of the present invention and together with a
description, serve to explain the principles of the
invention. In the drawings:

Fig. 1 is a top plan view of a schematic illustrating a
15 sheet of the unmolded compound utilized to form the
composite of the invention;

Fig. 2 is a perspective view of a plurality of the
sheets as illustrated in Fig. 1;

Fig. 3 is a perspective schematic view of a drill well
20 mandrel formed using the present invention;

Fig. 4 is an enlarged, sectional view of a portion of
the threads from a mandrel made with prior art composite
material;

Fig. 5 is an enlarged, section view of the threads of a
25 mandrel similar to that of Fig. 4 but formed from the
composite of the present invention;

Fig. 6 is a side schematic view of a molding device
useful in producing a composite tool of the present
invention;

30 Fig. 7 is an end view of the device illustrated in Fig.
6. with the premolded composite material in position for
molding to form a mandrel tool;

Fig. 8 is a top plan view of a fabric reinforcement
useful in another embodiment of the present invention;

35 Fig. 9 is a schematic illustrating a mold portion with
a composite precursor for another embodiment of the present
invention; and

Fig. 10 illustrates the formation of yet another
embodiment of the present invention utilizing the mold
arrangement illustrated in Fig. 9.

Detailed Description of the Preferred Embodiments

Referring to Figs. 1-3, sheet 10 is a composite made up of a plurality of fibers 12 embedded in a resin 14. While the fibers 12 may be random in nature, they are preferably oriented in the general direction of the greatest forces to be applied to the finished part, which in the case of a mandrel 16 (Fig. 3) is the longitudinal axis 15 of the sheet 10.

Fig. 2 illustrates the stacking of a plurality of these sheets 10, which stack 11 is then utilized to form the molded structure 16 as illustrated in Fig. 3. In this specifically illustrated embodiment, the molded structural device 16 particularly illustrated is that of a downhole mandrel useful in drilling well bores. It should be noted, however, that the present invention may be used for any type of expendable or destructible structural device that is designed to replace metal components or tools currently in use, and thus have the structural and tensile strength of metal but have low abrasive strength so as to be readily expendable. Specific examples in the drilling industry include mandrels, plugs and packers.

Referring to the preferred, illustrated embodiment, the mandrel 16 is basically a tube formed with external threads 18 on each end thereof, and internal threads, 20 on one end thereof. A mandrel is a tubular device that is placed in bores holes, one atop the other, with an area of the bore hole exposed where there is no mandrel. Thus, an area can be isolated for pumping purposes. However, when it is desired to move operations to another portion of the bore hole, the mandrels must be removed or destroyed in place. Previous hereto, rock drilling bits abraded the metal mandrels very slowly. The alternate maneuver was to insert a metal drilling bit and then change back to a rock drilling bit after the mandrels were destroyed. In either case, a great deal of time was expended.

As I stated earlier, replacement metal devices and components of various sorts have been previously addressed by various industries. Phenolic resins, either

1 unreinforced, filled with powders or filled with short
fibers of cotton or glass, have been utilized. However,
parts fabricated from such composites have been
unsatisfactory in certain applications because their tensile
5 strengths, sheer strengths, stiffness and other important
parameters have not been nearly as great as those of the
metal components they were designed to replace. In
accordance with the present invention, however, it has been
determined that certain combinations of materials and
10 methods allow replacement parts for metal to be designed
from resins reinforced by elongated fibrous materials.
Preferred resins include, but are not limited to, epoxies,
vinyl esters and polyesters, in combination with long (i.e.
greater than 1/2 inch) fibers, including but not limited to
15 glass fibers, aramid fibers and carbon fibers. While these
long fiber composites typically display greatly improved
bulk physical properties as compared to the short fiber
phenolic materials previously described, the present
invention also provides a distinct advantage in that by
20 controlling the fiber volume, fiber length and fiber
orientation, both before and during the molding process, the
physical properties in specific areas or portions of the
part can be engineered in order to better resist the forces
applied to those specific portions of the part when the part
25 is put into use. Thus, composite metal replacement parts
having varied properties within itself may be designed
utilizing the composite arrangement of the present
invention.

As indicated above, the preferred resins include
30 epoxies, vinyl esters and polyesters. The phenolics
previously utilized in prior art composites are not useful
with the present invention, even in conjunction with long
fiber materials. This is because it was found that the
materials compounded from phenolic typically displayed
15 physical properties that were at least 20% less than
materials combined with the epoxies and vinyl esters of the
present invention with equally long fiber reinforcement.
Because most, if not all, short fiber phenolic materials
have tensile strengths at or below 12,000 psi with other

physical properties also being significantly below those of metals, such as cast iron tensile strength of 30,000-60,000 psi, phenolic replacement parts, even if very thick, will still not meet the requirements of many metal replacement applications.

Utilizing the present invention, replacement composite parts may be designed with physical properties equal to or even exceeding those of the original metal part. With appropriate material choice, proper compounding, proper control of fiber alignment before and during processing, the replacement parts may be designed with tensile strengths having a range of 25,000-100,000 psi or greater. Moreover, an important aspect of the present invention is that a single metal replacement part may be developed with different portions thereof having different physical properties. For example, some portions of a part might be designed to be more flexible, while other portions may be designed to be stiffer, some portions stronger, while some portions being able to resist internal pressure or external crushing.

The mandrel 16 illustrated in Fig. 3 is a cylindrical tube having each end threaded externally 18 and one end internally 20. The mandrel is utilized within a well casing so that it must be capable of withstanding large internal pressures. In order to withstand such pressures, the mandrel must have high tensile and compressive strength, the preferred burst pressure being in the neighborhood of 30-60,000 psi. However, use of the mandrels are such that they remain in the well bore as previously indicated. Therefore, once the mandrels are no longer required, they must be drilled out or abraded away. Previous hereto, the process of drilling out the metal mandrel was a long and tedious one which increased the length of drilling time. This is because the metal mandrel was drilled out by using a rock drilling bit, which took excessive amounts of time to abrade away the mandrel. Alternatively, the drill string was removed from the hole to replace the rock drilling bit with a metal drilling bit to specifically drill through the mandrel, at which time the string was then removed again to

1 reinstall the rock drilling bit. Either of these
traditional techniques increased the drilling time
considerably. The composite structure of the present
invention, although it has a high compressive and tensile
5 strength, nonetheless has a low abrasion resistance which
permits it to be readily drilled through and destroyed by a
rock drilling bit. This reduces significantly the amount of
time required to drill through the mandrel.

10 A key feature of the invention which permits the high
compressive and tensile strength, but provides a limited or
low abrasion resistance, is the high aspect ratio of the
fibers in the composite, in addition to the choice of resins
and fibers themselves. The aspect ratio is the ratio
15 between the length of the fiber to the diameter of the
fiber. In preferred form, the fibers utilized with the
present invention are equal to or greater than 1/2 inch and
are preferably from 1/2 - 2 inches in length. In some
instances, the fibers can be continuous along the length of
the sheet 10 and thus along the length of the device 16, to
20 provide extremely high compressive and tensile strength.
The high aspect ratio fiber which has a small diameter as
opposed to the length of the fiber, substantially increases
the amount of surface availability to transfer force from
the resin to the fiber. In preferred form, the composite
25 structure of the present invention comprises a resin of
bisphenol-a-epoxy or vinyl ester having fiberglass fibers
of engineering standard, high strength, or chemically
resistant-type. Preferably, the aspect ratio is greater
than 1,000. More preferably, the aspect ratio is in the
30 neighborhood of 2,500-90,000 or more, in the case of
continuous fibers, and most preferably in the neighborhood
of 2,500-5,000.

Another advantage to the present invention is in the
threading and thread connection of any metal replacement
35 devices, and in particular of the illustrated mandrel in
Fig. 3. Referring to Figs. 4 and 5, Fig. 4 represents a
prior art arrangement utilizing phenolic resins and short
fibers. As is illustrated, the teeth 22 of the thread
portions 18' are for the most part void of any short fibers

1 24 and are generally made up of resin 26 and filler 28.
Thus, the teeth 22 of the threads 18' are resin rich, which
tended to cause stripping of the threads 18' under high
pressure since there are relatively few adhesive fibers
5 within the teeth 22. Referring to Fig. 5, the threads 18 of
the present invention include teeth 22 which have a
substantial number of the long fibers 30 therein. In fact,
the teeth 22 are fiber rich as opposed to resin rich as in
the prior art 18'. The fiber rich teeth 22 are due to the
10 fact that the fibers 30 are relatively long in length and
are thus pressed into the teeth 22 and, in fact, thread
themselves through several teeth 22, thereby increasing
their strength to act together. The results are that the
thread portions of the mandrel 16, or any other device
15 having threads 18, are very strong and do not tend to shear
under high pressure.

Such expendable, molded composite devices, as
replacement parts for metal components, have a wider range
of application because of a number of unique features.
20 First, the tensile properties of such composite components
equal or exceed those of the original metal part, which will
allow this type of replacement part to be fabricated within
the same design envelope as a metal part or even less.
Second, the shear strength of such a composite replacement
25 material is possibly less than the original metal material
shear strength. However, by virtue of the long fiber
reinforcement being molded actually down into the threads 22
on the ends of the mandrel 16 as described above, with these
fibers being long enough to pass both into and out of
30 multiple threads, and by virtue of these long fibers being
able to share the load that would be required over a
relatively large area, the threads on a metal replacement
composite part designed from this composite material are
placed in tension as well as shear. This results in threads
35 that perform better than any short fiber reinforced resin,
and also better than is apparent from the bulk shear
strength of the replacement material. Actual testing of
mandrels formed from the present invention correlate with
this.

1 Referring to Figs. 1-3, 6 and 7, the mandrel 16, as
well as any other desired composite device, may be molded
into metal replacement components using compression and/or
transfer molding techniques. To form the mandrel 16, a mold
5 32 having a bottom mold portion 34 and a top mold portion 36
is provided. A rod 38 is also provided to form the center
cavity of the mandrel 16. In the preferred form, the bottom
mold 34 is a female mold and is operated by placing a
plurality of the composite sheets 10 down within the female
10 cavity 40. The center rod 38 is then placed within the
female cavity 40 on top of the layered sheets 10. A
plurality of sheets 10 are then placed over the rod 38. The
upper mold 36, having a male cavity 42, is then pressed
downwardly into the bottom mold 34 so as to compress the
15 overlaid sheets and underlaid sheets 10 around the rod 38
within the male and female cavities 42, 40. The male upper
mold 36 is guided into position by guideposts 44 and sockets
46. The female cavity 40 has threaded grooves 48 at either
end thereof, while the male cavity 42 likewise has threaded
20 grooves 50 at either end thereof to form the external
threads 18 on the mandrel 16. In similar fashion, a forward
portion 54 on the rod 38 also has threaded grooves to form
the internal threads 20 of the mandrel 16.

In preferred form, the rod 38 and the layers of
25 uncompressed composite 10 are positioned as illustrated, the
molds 34, 36 being brought together and heated under
pressure. Preferably, the composite material 10 is
pressurized 2,500-4,000 psi for a sufficient time and
temperature such that maximum density of the composite
30 material and sufficient flow so that all interstices and
junctures between the sheets 10 are completely filled.

As indicated previously, one of the principal
advantages of the present invention is that it may function
as a substitute for metal devices or components in a wide
35 variety of different applications from automobiles to
drilling well bores. Regardless of this application, the
composite materials should be utilized in an environment
which will not tend to degrade the composite material and
thus reduce the strength of the composite device. Table III

below indicates a summary of the chemical resistance of composite materials constructed in accordance with the present invention as compared to the prior art phenolic composite. As can be seen from Table I, the composite device of the present invention has much better chemical resistance to a wider variety of chemical materials found in the environment than the prior art phenolic composite.

Table I

Chemical Resistance of Composite
Materials Compared to Phenolic

CHEMICAL ENVIRONMENT	MATERIAL DESCRIPTION		
	III	I & II	Phenolic
Aliphatic Hydrocarbons	Good	Ex	Ex
Aromatic Hydrocarbons	Good	Good/Ex	Ex
Oils, Fats, Waxes	Ex	Ex	Ex
Fully Halogenated Hydrocarbons	Ex	Ex	Ex
Partly Halogenated Hydrocarbons	Good	Good	Ex
Alcohols Monohydric	Ex	Ex	Good
Alcohols Polyhydric	Ex	Ex	Ex
Phenols	Fair	Fair	Ex
Ketones	Fair	Fair	Good
Esters	Fair	Good	Good
Ethers	Fair	Fair	Ex
Conc. Inorganic Acids	Good	Fair	Fair/Poor
Dilute Inorganic Acids	Ex	Ex	Fair/Good
Conc. Bases	Fair	Ex	Poor
Dilute Bases	Good	Ex	Poor
Salts - Acid	Ex	Ex	Ex
Salts - Neutral	Ex	Ex	Ex
Salts - Basic	Good	Ex	Fair
Conc. Organic Acids	Good	Fair	Good
Dilute Organic Acids	Good	Good	Fair
Conc. Oxidizing Acids	Poor	Poor	Poor
Dilute Oxidizing Acids	Fair	Fair	Poor
Sunlight and Weathering	Good	Good	Good

All of the composite materials I-III included either a vinyl ester resin (III) or a bisphenol-a-epoxy resin (I & II) having 60-70 weight percent of glass fiber. Composite I had the glass fiber laid in a directional manner substantially parallel with the longitudinal axis of the sheet 10. Composites II and III were made with the glass fibers placed within the resin in a more random fashion. The phenolic material was a glass fiber reinforced phenol having short fiber lengths as described above.

1 The composite components of the present invention also
2 have an excellent temperature resistance in terms of
3 maintaining their tensile and flex strength at elevated
4 temperatures such as found in certain engine compartments or
5 such as found in bore holes at depth. This is true also in
6 corrosive environments at temperatures approaching 300°F.
7 Thus, composite devices constructed in accordance with the
8 present invention will not tend to fail when utilized in
9 higher temperature environments, and therefore function
10 quite well as metal replacement components.

11 Downhole mandrel 16, as illustrated in Fig. 3, may be
12 manufactured using the method and mold described in Figs. 6-
13 7. Depending on the diameter of the rod 38, a thin wall
14 mandrel yielding a larger inner diameter device, or a thick
15 wall mandrel producing a thinner diameter device, may be
16 manufactured. However, the burst strength of such mandrels
17 will be different. For example, a mandrel 16, manufactured
18 in accordance with the method and mold described above, may
19 be made having an outer diameter of 2.375 inches and an
20 inner diameter of 1.333 inches with a wall thickness of
21 0.521 inches. Material strength for this, as well as the
22 subsequent mandrel example, is 50,000 psi, and the burst
23 strength results in about 39,085 psi. A second mandrel 16
24 is manufactured having the same outer diameter of 2.375
25 inches. However, a wider rod 38 is utilized so as to form
26 an inner diameter of 1.754 inches, resulting in a wall
27 thickness of 0.311 inches. The material strength is the
28 same 50,000 psi, and the resultant burst strength, however,
29 is reduced to 17,702 psi.

30 In either of these instances, however, the burst
31 strength is significantly greater than equivalent type of
32 mandrel made from the phenolic material described above.
33 Utilizing the same measurements as given above, phenolic
34 material at 12,000 psi material strength will result in a
35 burst strength of 9,380 psi for the thick wall mandrel and
36 only 4,249 psi burst strength for the thin wall mandrel.
37 Therefore, it can be readily seen that a mandrel, or any
38 other tool or component, constructed in accordance with the
39 present invention has a significantly greater burst strength

1 than mandrels made from composite materials known previously
hereto. These burst strengths are sufficiently adequate to
allow the mandrels manufactured in accordance with the
present invention to readily replace metal mandrels, and
5 thereby have the inherent advantages of the composite as far
as being expendable as described above.

An alternate embodiment and manufacture of mandrel 16
utilizing the mold substantially as illustrated in Figs. 6
and 7, is illustrated in Figs. 8-10. Fig. 8 illustrates a
10 woven fabric 60, which is produced from long fibers, in fact
continuous in length, woven together and impregnate with the
resin as described above. This particular woven fabric 60
may be utilized to produce reinforced threads on a mandrel
16. This is performed by utilizing the same mold 32 as
15 illustrated in Fig. 7. However, an alternate form of rod
38' having threads 62, are provided. This is illustrated in
Fig. 9.

As illustrated in Fig. 10, the woven fabric 60 is
wrapped around the rod 38' and then the sheets 10 of
20 uncompressed composite material are wrapped around the non-
threaded portion of the rod 38' over the fabric layer 60.
Compression molding in the matched die molds 34, 36 form the
outside of the part or mandrel and force the fabric layer 60
into the thread 62 of the rod 38', forming female threads on
25 the internal diameter of the molded mandrel 64. In
addition, if the molded mandrel 64 or other molded device
are required to be extremely strong in tension or extremely
stiff in bending along its major longitudinal axis, then the
continuous fiber reinforcement applied along the
30 longitudinal axis of the part from the woven fabric 60 will
enhance these properties. All of these possibilities are
realized using compression molding techniques with the
composite of the present invention and are not available to
a compression or injection molded part made from just short
35 fiber reinforced phenolics as in the prior art. In
addition, layers of the fabric 60 would also serve to
increase burst strength as well as to serve to improve crush
resistance of a mandrel 64.

As a final example, continuous fibers, spiral continuous fibers or braid continuous fibers can be filament wound in any combination with fabric layers 60 and random mat layers over rods 38 that are of appropriate shape. Such rods or other mold portions could be made of low melt temperature metal such as bismuth alloy, or of wax. Such techniques in combinations allow incredibly greater latitude in the design of high strength, engineered, metal replacement parts, including but not limited to easily drillable downhole products for the drilling industry, as well as any other type of expendable metal replacement part.

As can be seen from the above, the present invention provides for expendable, molded structural products and devices which are useful in a wide variety of industries. These are particularly useful as drillable downhole products for the drilling industry. The products are of sufficient structural and compressive strength to be able to function as metal replacement parts in a wide variety of applications. However, because of the unique nature of the present invention, the products have a very low abrasion resistance and thus are readily expendable or, in the case of the drilling industry, readily drillable and destructible so as to remove them from the well by simply utilizing a rock drilling bit, without an extensive increase in the amount of drilling time necessary. Devices produced with the present invention provide some unique alternatives in a wide variety of applications to replace metal products or metal components which either need to be destroyed in situ or wherein weight is of a major concern.

The foregoing description and the illustrative embodiments of the present invention have been shown in the drawings and described in detail in varying modifications and alternate embodiments. It should be understood, however, that the foregoing description of the invention is exemplary only, and that the scope of the invention is to be limited only to the claims as interpreted in view of the prior art. Moreover, the invention illustratively disclosed herein suitably may be practiced in the absence of any element which is not specifically disclosed herein.

1 The embodiments for which an exclusive property or
privilege is claimed are defined as follows:

5 1. An expendable, molded device comprising a composite
of resin and fiber molded into a pre-selected shape, said
composite including an effective amount of fiber having an
aspect ratio sufficient to produce a device with high
compressive and tensile strength but having limited abrasion
resistance.

10 2. The device as claimed in Claim 1, wherein said
fiber aspect ratio is greater than about 1,000.

3. The device as claimed in Claim 2, wherein said
fiber aspect ratio comprises 2,000-90,000.

4. The device as claimed in Claim 3, wherein said
fiber aspect ratio comprises 2,500-5,000.

15 5. The device as claimed in Claim 1, wherein said
fiber is substantially continuous and aligned in the
direction of the major forces to be applied to said device.

20 6. The device as claimed in Claim 1, wherein said
effective amount of fiber comprises approximately 60-70% by
weight of said composite.

7. The device as claimed in Claim 1, where said
composite is molded at approximately 2,000-4,000 psi.

25 8. The device as claimed in Claim 1, wherein the
abrasion resistance of said composite is sufficiently low to
permit rapid abrasion by metal.

9. The device as claimed in Claim 8, wherein the
abrasion resistance of said composite is sufficiently low to
permit said composite to be easily drilled through and
abraded away by a rock drill bit.

30 10. The device as claimed in Claim 1, wherein said
resin is selected from the group consisting of epoxies,
vinyl esters and polyesters, and wherein said fibers are
selected from the group consisting of fiberglass, aramids
and carbon fibers.

35 11. The device as claimed in Claim 1, wherein said
fibers are equal to or greater than 1/2 inch in length.

12. The device as claimed in Claim 11, wherein said
fibers are elongated and are from 1/2 - 2 inches in length.

13. A drillable, downhole tool for use in a well bore comprising a composite body of resin and fiber molded into a predetermined shape, said composite including an effective amount of fiber having an aspect ratio sufficiently high to provide said body with high compressive and tensile strength and low abrasion resistance to permit said tool to be drillable.

14. The tool as claimed in Claim 13, wherein said effective amount of fiber comprises approximately 60-70 weight per cent of said composite body.

15. The tool as claimed in Claim 13, wherein said fiber is sufficiently elongated relative to its diameter to provide said high aspect ratio.

16. The tool as claimed in Claim 15 wherein said fiber aspect ratio is greater than about 1,000.

17. The tool as claimed in Claim 16, wherein said fiber aspect ratio comprises 2,500-5,000.

18. The tool as claimed in Claim 13, wherein said fiber is substantially continuous and aligned in the direction of the major force to be applied to said tool.

19. The tool as claimed in Claim 13, wherein said abrasion resistance is sufficiently low such that said tool is destructible in situ within said well bore by a rock drill bit.

20. The tool as claimed in Claim 13, wherein said tool comprises a downhole mandrel having a burst strength of approximately 30,000-60,000 psi.

21. The tool as claimed in Claim 20, wherein said fiber is sufficiently elongated to provide said high aspect ratio and is substantially aligned with the longitudinal axis of said mandrel.

22. A drillable downhole mandrel for use in a well bore comprising a composite body of resin and fiber molded into a mandrel, said said composite comprising an effective amount of long fiber having a high aspect ratio sufficient to provide said body with high compressive and tensile strength and sufficiently low abrasion resistance to permit said mandrel to be readily destroyed in situ by being drilled through.

1 23. The mandrel as claimed in Claim 22, wherein said
resin is selected from the group consisting of epoxys, vinyl
esters and polyesters, and wherein said long fibers are
selected from the group consisting of fiberglass, aramids
5 and carbon fibers.

 24. The mandrel as claimed in Claim 22, wherein said
composite comprises vinyl ester having 60-70 weight percent
fiberglass fibers.

10 25. The mandrel as claimed in Claim 22, wherein said
fiber aspect ratio is greater than about 1,000.

 26. The mandrel as claimed in Claim 25, wherein said
fiber aspect ratio is 2,500-5,000.

15 27. The mandrel as claimed in Claim 22, wherein said
long fibers are elongated and aligned substantially with the
longitudinal axis of said mandrel.

 28. The mandrel as claimed in Claim 27, wherein said
fibers are substantially continuous along the length of said
mandrel.

20 29. The mandrel as claimed in Claim 22, wherein said
mandrel has a burst strength of approximately 30,000-60,000
psi.

25 30. A drillable downhole tool for use in a well bore
comprising a non-metallic tool body having high compressive
and tensile strength yet effectively low abrasion resistance
to permit said tool to be destructible in situ within said
well bore by a rock drill bit.

 31. The tool as claimed in Claim 30, wherein said
compressive and tensile strength are sufficiently great to
provide a burst strength of about 30,000-60,000 psi.

30 32. The tool as claimed in Claim 30, wherein said body
comprises a long fiber composite having resin and fiber
combined to provide a high fiber aspect ratio.

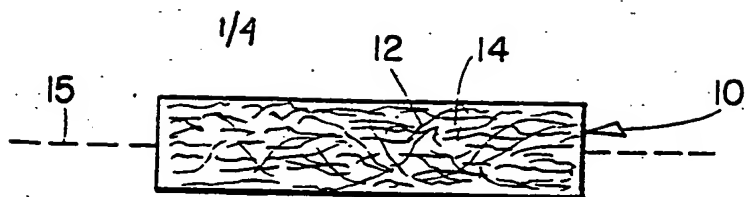


FIG. 1



FIG. 2

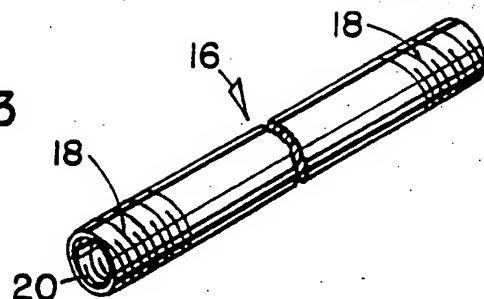


FIG. 3

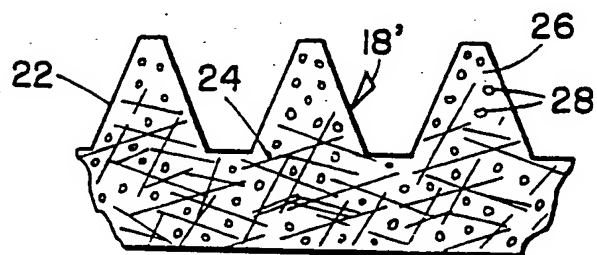


FIG. 4

Prior Art

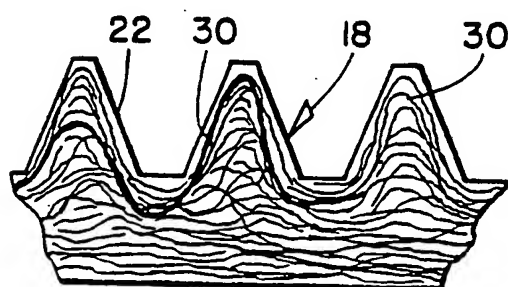
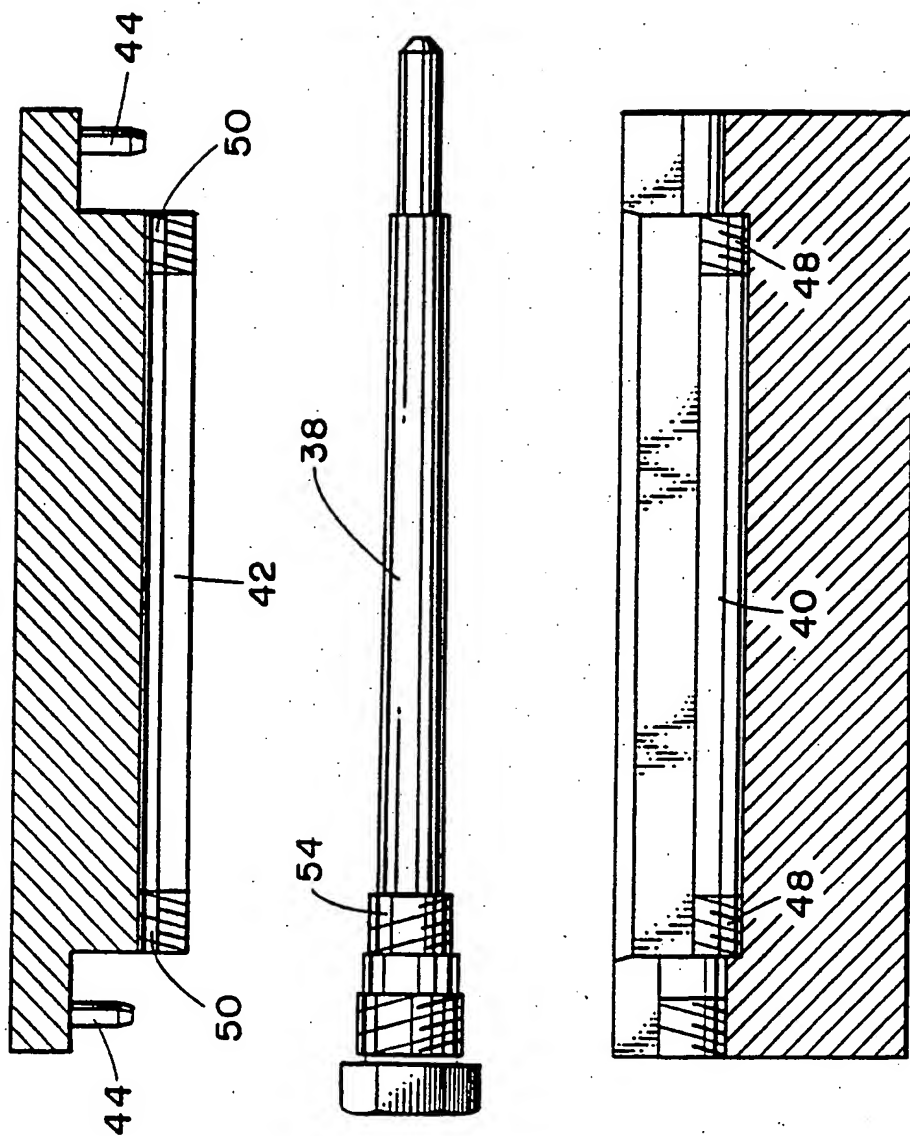


FIG. 5

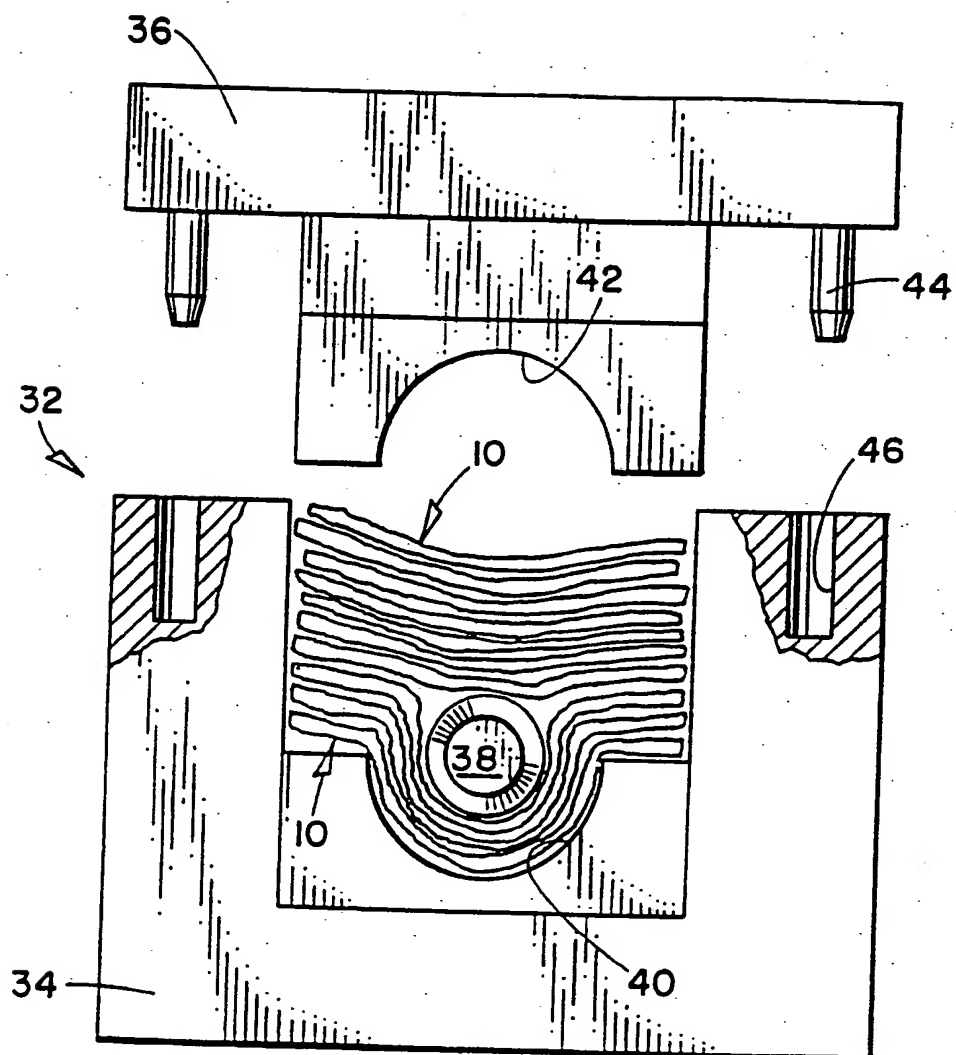
-2/4

FIG. 6



3/4

FIG. 7



4/4

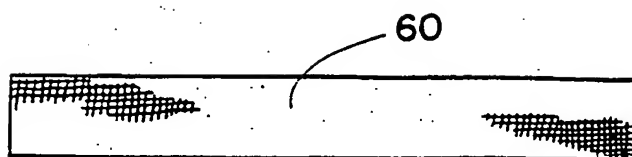


FIG. 8

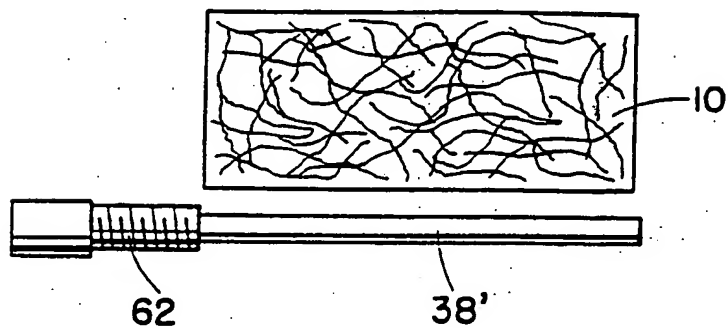


FIG. 9

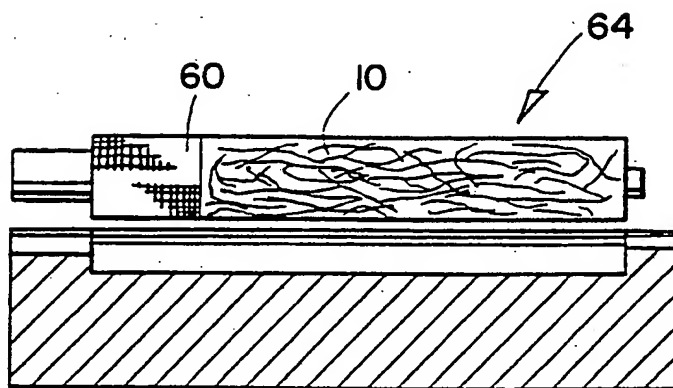


FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 92/04365

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ⁶		
According to International Patent Classification (IPC) or to both National Classification and IPC Int.C1.5 E 21 B 33/12 B 29 C 67/14		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
Int.C1.5	E 21 B B 29 C	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹		
Category ⁹	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	US,A,4708202 (SUKUP) 24 November 1987 see the whole document	1,5,8,9 ,10,13, 15,18, 19,20, 21,30- 32
P,X	--- EP,A,0454466 (HALLIBURTON) 30 October 1991 see column 3, line 40 - column 4, line 31; claims 1-5; figures 1,2	1,8,9, 13,15, 19,22, 23,27, 28,30, 32
A	--- FR,A,2567807 (BRONZAVIA) 24 January 1986 see page 1, lines 12-26; claims 1,3,4,6,7,8; figures 1-6 --- -/-	1,10,15 ,21,23, 27,32
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>¹⁰ Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> </div> <div style="width: 45%;"> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"d" document member of the same patent family</p> </div> </div>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
20-08-1992	11.09.92	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	FONSECA Y FERNANDEZ	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		Relevant to Claim No.
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	
A	WO,A,8809263 (TEXTILVER) 1 December 1988 see page 1, lines 1-11; page 5, lines 1-11 ---	5,18,28, 32
A	EP,A,0324630 (RAYCHEM LTD) 19 July 1989 see claims 1,6,20 ---	1,10,23
A	EP,A,0104958 (ALBANY INT.) 4 April 1984 see abstract; figures 1-4 ---	5,8,27, 28
A	EP,A,0191337 (HAREN) 20 August 1986 see abstract; figure 1 -----	1

**ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.**

US 9204365
SA 61092

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 08/09/92
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4708202	24-11-87	None	
EP-A- 0454466	30-10-91	AU-A- 7594991	07-11-91
FR-A- 2567807	24-01-86	None	
WO-A- 8809263	01-12-88	GB-A- 2204888	23-11-88
		AU-A- 1932788	21-12-88
		EP-A- 0368872	23-05-90
		JP-T- 3500148	17-01-91
		US-A- 4961977	09-10-90
EP-A- 0324630	19-07-89	AU-A- 2842689	13-07-89
		AU-A- 8550891	05-12-91
		EP-A- 0453053	23-10-91
		JP-A- 1238923	25-09-89
EP-A- 0104958	04-04-84	None	
EP-A- 0191337	20-08-86	DE-A- 3504829	14-08-86

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

THIS PAGE BLANK (USPTO,